APPENDIX E
SUDHAKAR TEST REPORT PIT 9 EXPLOSIVE TESTING

Sudhakar Test Report
Pit 9 Explosive Testing
(16 August 1999)

Report Prepared by
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Three series of explosive testing was performed at the request of the Pit 9 Independent Technical Review Panel (ITRP) and the Department of Energy. These included the following:

- The first series of tests was performed to establish a baseline using ammonium nitrate (two tests performed). This was accomplished on 3 August 1999. The weather was clear and the temperature was 98° F with a slight SW wind.
- The second series of tests was performed using a nitrate/oil surrogate, using both dry and wet samples (five tests performed). These tests were conducted on 6 August 1999 with Mike Coburn present. The weather was clear and the temperature was 100° F with a slight SW wind.
- A third series of tests was performed using surrogate nitrate/oil samples with 5% moisture content (two tests) and surrogate nitrate/graphite samples (two tests performed). These tests were performed on 11 August 1999. The weather was clear and the temperature was 100° F with light varying winds shifting from the NE to the SW.

All testing was performed at the International UXO Training Program's demolition range located at Texas A&M's Riverside Campus near Bryan, Texas. The testing was video taped and the ITRP has an edited version. Attached is the original Statement of Work for the initial surrogate nitrate/oil mix along with information concerning the chemicals used. Also, at the end of the report is a test summary table.

A description of the testing follows:

Ammonium Nitrate Testing – Two samples of ammonium nitrate were prepared for the testing. Sample 1 consisted of 3 kg of 34% ammonium nitrate placed inside a one-gallon paint can. The sample was buried in a hole and primed with an electric blasting cap *(a number 8 blasting cap consists of approximately 1 gram of a combination of lead azide, lead styphnate and RDX)* and a 1/3-pound pentolite booster *(Pentolite consists of 50% TNT and 50% PETN)* then covered with two feet of sandy soil. There was some contribution from the ammonium nitrate. Most of the soil was thrown into the air with some settling back into the hole and there was some minor cratering at the edge of the hole.

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Sample 2 consisted of a 3 kg mix of ammonium nitrate (94% by weight) and diesel fuel (6% by weight). This is the standard ratio for blasting grade ammonium nitrate and fuel oil mix (*typically referred to as ANFO*). This sample was also place in a hole and primed with an electric blasting cap and a 1/3-pound pentolite booster then covered with two feet of sandy soil. The ANFO made a significant contribution to the explosion. The soil was thrown out of the hole with some large chunks of earth falling back into the hole. There was significant cratering around the hole.

Surrogate Nitrate/Oil Testing - Five samples were prepared for the testing. All samples except number 4 weighed 3 kg and were placed in one-gallon paint cans. The first sample consisted of table salt (90%) and Regal oil (10%). All other samples used the surrogate Pit 9 mix of sodium nitrate (60%), potassium nitrate (30%) and Regal oil (10%). Ten percent water (.3 kg) was added to sample number 4. The ingredients were mixed to a homogenous consistency in the cans. All explosive test samples were placed in a hole, primed and then covered with two feet of sandy soil. The cook-off sample (test number 5) was suspended over a burn pit consisting of a burn pan placed in a four-foot diameter hole and filled with wood and 1.5 gallons of diesel fuel.

Sample 1 (table salt/oil mix) was primed using an electric blasting cap and a 1/3 lb. pentolite booster. There was **no energetic reaction** from this sample.

Sample 2 (surrogate/oil mix) was primed using only a blasting cap. There was **no energetic reaction** from this sample.

Sample 3 (surrogate/oil mix) was primed with a blasting cap and a 1/3-pound pentolite booster. **There was an explosive reaction** from this sample. Mike Coburn and I estimated that the results were approximately 2/3 the power of the ammonium nitrate and fuel oil (ANFO) shot performed on 6 August.

Since there was a reaction from Test 3 we tested sample 4.

Sample 4 contained the Pit 9 surrogate mix plus 10% water (.3 kg). The sample was initiated using an electric blasting cap and a pentolite booster. There was **no energetic reaction from the surrogate mix.**

Sample 5 (surrogate nitrate/oil mix) was used for the cook-off test. The fire in the pit was initiated using a powder train/time fuse combination (time fuse is used to ignite a small bag of smokeless propellant which in turn ignites the diesel fuel and then the wood). There was **no violent reaction from the surrogate mix**. Over about a 20-minute period the burn produced smoke from the diesel fuel and wood. After that the fire produced a darker smoke indicating that the Regal oil in the mix was burning. At 24 minutes into the burn the can containing the sample

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fell into the dunnage and dumped its contents directly into the fire causing the nitrates to burn producing a white smoke. After about 45 minutes we put out the fire and investigated the burn. There was some unburned nitrate residue remaining in the burn pan.

Additional testing with 5% moisture samples and Nitrate/Graphite samples – Based on the energetic reaction of the dry surrogate nitrate/oil mix and the negative results of the same mix with 10% moisture, the Panel requested a third series of testing. These tests were performed to determine whether or not the surrogate nitrate/oil mix with 5% moisture would produce an energetic reaction and whether or not a surrogate nitrate/graphite mix would produce an energetic reaction. All samples weighed 3 kg. The surrogate nitrate/oil mix consisted of 60% sodium nitrate, 30% potassium nitrate and 10% regal oil by weight. 5% of water (by weight) was then added. The surrogate nitrate/graphite mix consisted of 47.33% sodium nitrate, 23.66% potassium nitrate and 29 % graphite. All samples were thoroughly mixed and prepared in one-gallon paint cans. They were then placed in a hole, primed and covered with two feet of sandy soil.

Sample 1 (surrogate nitrate/oil mix with 5% moisture) was primed using an electric blasting cap and a 1/3 lb. pentolite booster. **There was no energetic reaction** from this sample.

Sample 2 (surrogate nitrate/graphite mix) was primed using an electric blasting cap. **There was no energetic reaction** from this sample.

Sample 3 (surrogate nitrate/oil mix with 5% moisture) was primed using an electric blasting cap and a 1/3 lb. pentolite booster. This was a repeat of test 1 to verify the results. **There was no energetic reaction** from this sample.

Sample 4 (surrogate nitrate/graphite mix) was primed using an electric blasting cap and a 1/3 lb. pentolite booster. **There was no energetic reaction** from this sample. There was some burning of the graphite – smoke only, no flames. Fused pieces of the graphite were hot to the touch 10 minutes after the explosion.

The following individuals participated in the testing:

Rex Shipp	Sudhakar Company, Inc.
Richard Cummins	Sudhakar Company, Inc.
Fred Parrish	Sudhakar Company, Inc.
Doug Lamothe	Sudhakar Company, Inc.
Mike Coburn	ITRP Member
Paul Ihrke	Sudhakar Company, Inc.

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TEST SUMMARY TABLE

Test Number	Sample Composition	Initiation System	Observed Results
1	Ammonium Nitrate	Blasting Cap & Pentolite Booster	Partial energetic reaction (minor cratering)
2	Ammonium Nitrate 94% and Diesel Fuel 6%	Blasting Cap & Pentolite Booster	Energetic reaction – this is an industry standard for earth blasting
3	Table Salt 90% and Regal Oil 10%	Blasting Cap & Pentolite Booster	No energetic reaction
4	Surrogate Nitrate/Oil Mix	Blasting Cap	No energetic reaction
5	Surrogate Nitrate/Oil Mix	Blasting Cap & Pentolite Booster	Energetic reaction at about 2/3 the cratering of Test 2
6	Surrogate Nitrate/Oil Mix With 10% Moisture	Blasting Cap & Pentolite Booster	No energetic reaction
7	Surrogate Nitrate/Oil Mix	Wood, Diesel Fuel & Smokeless Powder	No energetic reaction. Oil burned then nitrates burned
8	Surrogate Nitrate/Oil Mix With 5% Moisture	Blasting Cap & Pentolite Booster	No energetic reaction
9	Surrogate Nitrate/Graphite Mix	Blasting Cap	No energetic reaction
10	Surrogate Nitrate/Oil Mix With 5% Moisture	Blasting Cap & Pentolite Booster	No energetic reaction
11	Surrogate Nitrate/Graphite Mix	Blasting Cap & Pentolite Booster	No energetic reaction. There was some burning of the graphite.

THIS IS THE SEQUENCE IN WHICH THE TESTS WERE PERFORMED AND COINCIDES WITH THE VIDEO TAPE

Paul Ihrke
Test Director

R. T. Shipp
Rex Shipp
Range Manager

Mike Coburn
Panel Member Observer

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Attachments

1. Explosive Testing Scope of Work (covers only the original scope)
2. Data sheet on chemicals used in the testing

EXPLOSIVE TESTING SCOPE OF WORK[1]

Conduct a series of tests to determine the energetic reaction of a surrogate Series 745 sludge containing 10% machine oil (60% NAO_3, 30% KNO_3 and 10% Texaco Regal R&O 32 machine oil).

Minimum testing includes:

1. A baseline test using a 1/3 lb. Pentolite booster inserted in 3 kg. of non-energetic salt and initiated with a blasting cap.
2. A dry mixture test using a 3 kg. sample of the above nitrate/oil mixture will be initiated with a blasting cap.
3. A dry mixture test using a 3 kg. sample of the above nitrate/oil mixture will be boosted with a 1/3 lb. Pentolite booster and initiated with a blasting cap.
4. If the mixture in either test 2 or 3 contributes to the explosion, then conduct a fourth test using a 3 kg. sample of the above nitrate/oil mixture with an additional .3 kg. of water. This will provide a sample with a 10% moisture content. It will be boosted and initiated as above.

During the above tests the samples will be confined, configured in a diameter of 6 inches, and covered with 2 feet of sand.

5. Conduct a cook-off test using a 3 kg. sample of the nitrate/oil mixture surrounded by combustible materials. The combustible materials will be initiated with a time fuse powder train and allowed to burn.

Videotape all testing and provide a copy of the videotape. Prepare and submit a written report to include as a minimum a description of the sample preparation, the test procedures, and results.

[1] Two other series of tests were directed by the DOE and performed on 3 August and 11 August. The first series was set up as a baseline using ammonium nitrate. The second was an expansion of the above scope of work. All testing is covered in the Sudhakar Test report dated 16 August 1999.

Information on chemicals used for the Pit 9 explosive testing

Ammonium Nitrate

Total nitrogen content	34%
Nitrate nitrogen	17%
Ammoniacal nitrogen	17%

Trade name – Amtrate Prills
Source – Mississippi Chemical Corporation

Sodium Nitrate

Assay:	min 99%
Insoluble matter:	.005%
Iodate:	.001%
Iodate and nitrate:	about 5 ppm IO_3 and .001% NO_3
Phosphate:	5 ppm
Sulfate:	.003%
Heavy metals:	5 ppm
Ca, Mg,and R_2O_2 Ppt:	.005%
Iron:	3 ppm

Meets ASC specifications
Manufactured by EM Science, part number SX0655-1

Potassium Nitrate

Assay:	min 99%
Insoluble matter:	.005%
Chloride:	.002%
Iodate:	5 ppm
Iodate and nitrate:	about 5 ppm IO_3 and .001% NO_3
Phosphate:	5 ppm
Sulfate:	.003%
Heavy metals (as Pb):	5 ppm
Ca, Mg,and R_2O_2 Ppt:	.01%
Iron:	3 ppm
Sodium:	.005%

Meets ASC specifications
Manufactured by EM Science, part number PX1520-5

Graphite - Natural graphite, extra fine, 6199 - Manufactured by Cummings-Moore Graphite Company, part number HPGG16

Table Salt (NaCl) manufactured by Morton Salt Company

Machine/cutting Oil – Regal R&O 32 manufactured by Texaco

Diesel Fuel number 2 obtained from Exxon

INPUT TO THE PIT 9 INDEPENDENT TECHNICAL REVIEW PANEL CONCERNING THE POTENTIAL FOR AN EXPLOSION DURING SONIC DRILLING
25 AUGUST 1999

Background

A Technical Independent Review Panel (ITRP) was commissioned by the Department of Energy to review the potential for fires and/or explosions associated with Pit 9 waste during sonic drilling activities at the Idaho National Engineering and Environmental Laboratory (INEEL). I was selected to support the ITRP as an explosives safety consultant.

Pit 9 is filled with a large number of barrels and other containers containing waste materials from the Rocky Flats nuclear production facility. Of specific concern is the mixing of series 745 sludge (containing nitrate salts), series 743 sludge (containing cutting oil and other organic materials like wood and rags) and materials like graphite fines and metal fines. These materials were placed in unlined barrels prior to 1970 and one must conclude that the barrels are corroded to the extent that some mixing of these materials has occurred. Since some combinations of nitrates and fuels can form explosive mixtures (ammonium nitrate and diesel fuel for example) if properly combined and energized, there may be the potential for such a mixture in Pit 9. If there is such a mixture in Pit 9, then there is the potential that the mixture could react explosively when energized by the drilling action.

My contribution as an advisor is based on over 20 years of military and commercial ammunition and explosives experience. This includes operational experiences as an Explosive Ordnance Disposal officer, an ammunition plant commander, as a member of the Department of Defense Explosives Safety Board and as Vice President of Sudhakar's Explosives Operations Group.

Panel Actions

The Panel, along with a number of advisors, reviewed all available pertinent data regarding the materials present in Pit 9 and the energetics associated with sonic drilling operations. The Panel concluded early-on that some additional testing was needed to help in the evaluation process. Actual test results using surrogate mixes of the Pit 9 material played a major role in the Panel's evaluation of the potential for an explosion or fire occurring from sonic drilling in Pit 9. These tests included sensitivity testing of surrogate Pit 9 materials at Los Alamos National Laboratory and initiation testing of surrogate Pit 9 materials performed by Sudhakar Company, Inc. personnel at the International UXO Training Program (IUTP) demolition range. Additional testing of actual Series 745 sludge and mixtures of the sludge was performed by the Brookhaven National Laboratory. The results of the IUTP testing are attached to this report.

Data/Information Review

I reviewed the available data regarding the material present in Pit 9, the dynamics of sonic drilling and the test reports. Also, I was present during the briefings and interviews at the Panel meetings in Idaho Falls. These included the interviews with David Green and Dr. David Quigley. I consulted frequently with Mike Coburn of the Panel.[1] I also discussed the issue of explosive nitrates with U.S. Army explosive safety personnel and members of the Department of Defense Explosives Safety Board.

Testing

The testing at Los Alamos and Brookhaven indicated that there was not a sufficient amount of sensitivity to heat, shock or friction to cause a reaction in the surrogate or actual Pit 9 materials. The Sudhakar initiation testing proved that a dry mix of the surrogate nitrate/oil mixture could be made to explode with a large enough booster (a 1/3 pound pentolite booster).[2] However, the mixture was not sensitive to a blasting cap, nor would it explode at a 5% moisture level (by weight) even with the pentolite booster.[3] Additional testing using a surrogate nitrate/graphite mixture would not explode even with the pentolite booster. Some of the graphite was fused by the explosion of the booster and smoldered for several minutes after initiation. The fused pieces of graphite were still warm to the touch after 15 minutes.

A cook-off test was conducted on a sample surrogate nitrate/oil mixture. The mixture did not undergo any violent energetic reaction. It did however burn producing first a dark oily smoke (burning of the Regal Oil) and then a white smoke when the nitrates spilled into the fire. After about 45 minutes there was some smoldering left and the fire was extinguished using dirt. Some of the nitrates were still unburned.[4]

Conclusions and Recommendations

Based on the information that I have read (concerning the materials in Pit 9 and the dynamics of sonic drilling), my discussions with a number of explosives experts and the results of the three test programs, I do not believe that sonic drilling into Pit 9 will cause an explosion of the nitrate-organic mixtures or of any combination of nitrate/graphite mixtures. In the unlikely (in my opinion) situation where the sonic drill might encounter a container of picric acid causing it to detonate, the detonation would not be sustained (would not propagate) within the mixtures present in Pit 9. This is primarily due to the fact that the amount of

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[1] Mike Coburn's evaluation is based on much of the same information, however, his is a more technical and documented reference.
[2] Sudhakar Test Report
[3] Ibid
[4] Ibid

picric acid or any other potential "booster like" substance would be much too small in size to cause a sustained reaction within the Pit 9 mixtures.

From a safety standpoint, and this is common practice in the explosives manufacturing business, irrigation at the drill tip using water will substantially reduce heat and friction. If the Panel has any concerns regarding the heat and friction generated by the drill tip then I would recommend irrigation. Even a small irrigation capability in conjunction with a reasonable refusal standard[5] will provide an additional level of safety to help prevent an explosion.

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Attachment
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[5] The refusal standard must be conservative enough to prevent the temperature at the bit from reaching the ignition temperatures of the mixtures in the Pit.